Coronary artery bypass surgery

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Abstract

For five decades now, coronary artery surgery has been shown to relieve angina and extend life expectancy in patients with severe coronary artery disease. Pioneered in the 1960s, it has grown to become the most commonly performed and most intensively studied surgical procedure in the world, and remains the gold standard method for coronary revascularization, especially in patients with the most severe disease. Although it is increasingly challenged by percutaneous techniques using stents, the last decade has witnessed a significant reduction in surgical mortality (currently almost 0.5% in elective patients) and morbidity despite being applied in an increasingly older and sicker population. The use of arterial grafts, especially using the left internal mammary artery, has resulted in significant improvements in long-term patency and clinical outcome. More recent technical advances include beating heart (off-pump) surgery, arterial revascularization and minimally invasive techniques.

Keywords Conduits; coronary artery bypass; ischaemic heart disease; MRCP; off-pump; revascularization

Key points

- Coronary artery bypass grafting (CABG) remains the gold standard treatment for most patients with multivessel and left main coronary artery disease
- The indications for CABG are twofold: symptomatic and prognostic
- CABG has a strong survival advantage over percutaneous coronary intervention
- Use of the internal mammary artery as a conduit for CABG results in superior graft patency and survival benefit
- CABG without the use of cardiopulmonary bypass (beating heart surgery) is a safe and effective alternative in experienced hands
- The optimal approach to the treatment of any patient with multivessel coronary artery disease is through the multidisciplinary 'heart team' approach

Introduction

Coronary artery disease (CAD) represents a major health burden in the developed world. It accounts for almost 70,000 deaths in the UK each year, making it one of the most common causes of death. It is currently the major leading cause of death in Europe. Each year, there are 2 million deaths from cardiovascular disease in the European Union, the main cause being CAD, which causes 16% of deaths in men and 15% in women. Over 115,000 revascularization procedures (>95,000 percutaneous and >20,000 coronary artery bypass grafting (CABG)) were performed in the UK in 2015. Revascularization (surgical or percutaneous) improves symptoms and quality of life in patients with CAD, but only surgical revascularization has been shown to also improve life expectancy.

Coronary artery bypass grafting

CABG is the most common surgical procedure performed on the heart, with approximately one million operations performed every year worldwide. Having recently celebrated the 50-year landmark since its inception, CABG has remained the gold standard treatment for patients with multivessel CAD. Furthermore, it is the most extensively studied surgical procedure, with follow-up data extending to several decades.

CABG is highly effective in relieving symptoms of ischaemic heart disease, as well as improving life expectancy in certain anatomical subsets; these benefits are magnified in patients with more severe disease or with impaired left ventricular function. Furthermore, CABG is a remarkably safe therapy. Improvements in medical, anaesthetic and surgical management have ensured improved mortality rates despite an increasing proportion of ageing and sicker patient populations.

Relief from angina and improved quality of life are achieved in most patients, but the main long-term drawback is vein graft failure leading to recurrent angina, myocardial infarction and death. The annual attrition rate of vein grafts is about 2–4%, leading to recurrent angina in 20% of patients at 5 years, and 40% at 10 years. However, the widespread use of arterial grafting, antiplatelet agents and statins is likely to improve graft longevity and subsequent outcome.

Indications

Randomized trials performed in the 1970s confirmed the superiority of CABG over medical therapy with respect to relief from angina and improved quality of life in symptomatic patients. The main trials included the Coronary Artery Surgery Study (CASS), Veteran's Administration Coronary Artery Bypass Trial and European Coronary Artery Bypass Trial. These studies served to define the population subsets most likely to derive prognostic benefit from surgery. A landmark meta-analysis confirmed the

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benefits of CABG, especially in high-risk patients.[1] All subsequent contemporary trials of percutaneous coronary intervention versus CABG show that, for most patients with significant CAD, CABG has a strong survival advantage, accompanied by a marked reduction in myocardial infarction and repeat revascularization.

The clinical indications for CABG are listed in Table 1.[2]

Risk assessment

Several systems of stratification can be used to estimate the risk associated with cardiac surgery. Risk stratification defines the ability to predict outcomes from a given intervention by arranging patients according to the severity of their illness. Thus, outcomes from surgery can be compared with those predicted by risk models. Risk stratification also serves to estimate the risks of surgery in individual patients, allowing careful comparison with the potential or perceived benefits. The most commonly used risk stratification systems include:

- **Parsonnet** – this model was originally developed in 1985 in the USA. Recent advances in clinical practice mean that it now overestimates the risk of mortality associated with cardiac surgery, and it is rarely used.
- **EuroSCORE** – developed in Europe and previously widely used in the UK, this is a better predictor of risk than the Parsonnet and readily used at the patient's bedside. However, it now consistently overestimates risk, and a modified, updated, more accurate version (EuroSCORE II; www.euroscore.org) is now available. This is derived from a more contemporary dataset that better reflects current cardiac surgical practice.
- **Society of Thoracic Surgeons risk calculator** – used in the USA, this extensive system (riskcalc.sts.org) provides measures of both mortality and morbidity.

Indications for surgery in ischaemic heart disease

Indications for myocardial revascularization

- Relief of angina (stable or unstable) unresponsive to medical therapy
- Congestive heart failure complicating acute myocardial ischaemia or severe CAD
- Cardiogenic shock after myocardial infarction

Anatomic considerations indicating prognostic benefit of CABG

- Left main coronary artery stenosis >50%
- Significant proximal LAD stenosis
- Left main equivalent disease: significant stenosis (>70%) of proximal LAD and proximal circumflex artery
- Two- or three-vessel CAD with impaired left ventricular function
- Two-vessel disease including a proximal LAD stenosis combined with left ventricular dysfunction

Other indications

- Mechanical complications of myocardial infarction including post-infarction ventricular septal defect, papillary muscle or ventricular wall rupture

CAD, coronary artery disease; CABG, coronary artery bypass grafting; LAD, left anterior descending.

Table 1

Conduits for CABG

The principle of CABG is to bypass diseased segments of the coronary circulation using arterial and venous conduits – the most frequently used are the left internal mammary artery (LIMA) and the long saphenous vein. Several other options (radial artery, gastroepiploic artery, cephalic vein) have been used, with varying results. Performance is judged on the basis of long-term patency and effect on clinical outcome. Patient factors, including coronary anatomy, also play an important part in the decision-making process. Figure 1 shows some of the graft configurations that can be used in CABG.

Left internal mammary artery

Initially used in the early 1970s, the LIMA conduit has grown remarkably in popularity after reports demonstrating superior patency rates (>90% at 10 years) and patient survival in comparison with saphenous vein grafts. The Cleveland clinic group reported an 11% improvement in 10-year survival in patients treated with an LIMA graft to the left anterior descending (LAD) artery[3]; this is now the conduit of choice to the diseased LAD and is the standard of care for patients undergoing CABG.

Bilateral internal mammary arteries

The superior performance of the LIMA leads intuitively to the assumption that the use of bilateral internal mammary artery (BIMA) grafts should maximize benefit. To date, the most powerful supporting evidence comes from a meta-analysis of >15,000 patients, and subsequently the Arterial Revascularisation Trial (ART). This is the only large randomized controlled trial comparing the clinical outcomes of CABG patients treated with single internal mammary artery versus BIMA grafts. Its 5-year interim results have not shown any difference in terms of survival between patients randomized to be given single or bilateral grafts.[4] However, longer follow-up is needed to draw final conclusions from the ART trial.

Routine use of BIMA grafts should be weighed against potential drawbacks, which include devascularization of the sternum (with a resulting increase in risk of wound complications, especially in obese patients with diabetes mellitus), prolonged operation time and technical challenges associated with its use. Current US and European guidelines encourage the use of arterial grafts, including BIMA, in patients with long-life expectancy and where the use of BIMA grafts confers little additional risk.

Long saphenous vein

The long saphenous vein was first used as a conduit for CABG in the 1960s and remains the most commonly used conduit (in contemporary practice vein grafts still account for around 80% of all grafts on the heart). It can be harvested using an open technique, but minimally invasive endoscopic approaches are increasingly used, with the aim of allowing earlier mobilization, reducing morbidity and shortening hospital stay. Patency rates at 10 years are around 50%, but this has improved in recent years with increased use of secondary prevention measures including antiplatelet agents and statins.

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